Evaluating the Energy and Carbon (IV) Oxide (CO 2) Reduction Resulting from Efficient Lighting at the University of Lagos, Nigeria

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Abstract
This study evaluated the economic and environmental potentials of improving the energy efficiency of the lighting technology at the University of Lagos, Nigeria. The energy audit report for the Faculty of Engineering, University of Lagos before retrofitting shows that all lighting fixtures in the lecture rooms are the 1.2 metre inefficient fluorescent lamps. The cost effectiveness of lighting retrofitting with Compact Fluorescent Lamps (CFL) and Light Emitting Diode tube (LED) lighting technology alternatives for the lighting system at Faculty of Engineering lecture rooms were analysed using economic indices such as life cycle cost analysis, net present cost, simple payback time, and internal rate of return. Relative to the existing system, installation of the two lighting technology alternatives would result in a 40 % and 72 % reduction of consumed energy respectively. With both technology alternatives paying back in less than two years, the LED technology returned a NPV of $35,791.76 (₦12.95M) compared to the $15,261.43 (₦5.24M) given back by the CLF lighting fixtures. If the alternative lighting technology that conserves the most electricity was installed, carbon dioxide emissions accompanying electricity usage would be reduced by about 72 % and a savings of 3.84 tonnes of oil would be achieved annually. From the study, it was established that the utilisation of energy efficient lighting system will reduce energy consumption; increase bills savings; and indirectly reduce carbon (IV) oxide emission from the fossil fuel used in powering the lamps

Keywords: Conservation, Efficiency, Electricity, Emission, Tariff

1.0 INTRODUCTION

CARBON (IV) oxide (CO_2) emission has become a major source of concern while its reduction is of interest to everyone and in every sector of the society. This is due to the negative effects it has precipitated on our global world in terms of global warming and recent trends of health hazards (Anomohanran, 2011). The adoption of energy efficiency and energy conservation techniques are therefore imperative to reducing the emission of greenhouse gases. This necessitates the adoption of energy efficiency and conservation techniques as imperative in mitigating greenhouse gas. Therefore, there is a need to improve on energy usage worldwide.

In developing economies, more than 40 % of the total energy consumed is in reference to the residential and the tertiary sectors, the major part of which are building structures (Perez-Lombard *et al.,* 2008). Consequently, buildings account for about one third of CO_2 emission worldwide (Farrou *et al.,* 2012). This is largely due to the inefficient use of energy in such buildings. Lighting systems consume approximately 30 – 40 % of energy demanded in commercial buildings (Perez-Lombard, Luis and Ortiz Jose, 2008). This conveniently amounts to one third of buildings' electricity bills. However, the use of electricity for lighting purpose worldwide is generally inefficient. Asides the aesthetic value it affords an environment, the lighting system is very important for all building occupants. It illuminates an environment for easy movement; enhance productivity as well as safety during work or other related human activities. The lighting system is, indispensable for every building. Therefore, the lighting system should be adequately designed in order to achieve the level of illumination required. Moreover, the rate of electricity consumption and the rate of carbon dioxide emission should be put into consideration while designing an energy efficient lighting system. Energy efficiency results from the utilisation of energy saving technologies that minimizes energy wastage and requires lower consumption to perform the same function (Ibrik and Mahmoud, 2002). Energy saving techniques includes the use of well-ventilated windows in buildings - which allow for natural light during the day, better building management and use of more energy efficient lighting systems. A typical example of energy efficiency is the Installation of LED or CFL, which uses less energy to produce same level of lighting, as against incandescent lamps or ballast florescent tubes. Energy conservation involves behavioural activities that result in consumption of less energy. Such activities may include using natural light in place of lamps where possible, painting of walls and ceilings with bright colours to improve light reflection, switching off redundant lamps, switching off electronic gadgets when not in use, lamp retrofit, etc. The rise in energy consumption, as a result of human activities that demand the use of lighting systems in various societies, has its negative effect on the environment (Stefano, 2000). The retrofitting of lamps can be regarded as both energy efficiency and an energy conservation technique. Consequently, the combination of energy efficiency and energy conservation techniques will result in energy cost reduction, reduced rate of greenhouse gases emission during consumption and also defer the addition of more generation to the national grid (Akinbulire *et al.,* 2014; Deossa *et al*., 2017; Oluseyi *et al.,* 2009; Ogbonnaya *et al.,* 2008). Energy efficiency and conservation are fundamental to energy sustainability. 'Sustainability' ensures that every generation meets its own energy requirement without compromising the energy needs of future generations. This can be achieved in the case of lighting systems through retrofitting i.e. the use of a more efficient and energy conservative lighting system to perform the lighting function. This will significantly reduce energy consumption, cost of energy, heat generated by the less efficient lamp, and the duration of the lighting equipment's replacement.

Several studies have explored ways of reducing CO_2 emission, energy consumption and energy cost. Some of them even went further to demonstrate retrofits for various kind of buildings (Radulovic *et al.,* 2011; Hee and Ku, 2014; Trifunovic *et al.,* 2009; Wall and Crosbie, 2009; Sukri *et al*., 2012; Ganandran *et al.,* 2014; Abolarin *et al*., 2013; Li *et al*., 2010; Mahlia *et al*., 2005; Mahlia *et al.,* 2011; Razak *et al.,* 2011; Oluseyi *et al.,* 2016). A study conducted by Li *et al.* (2010) on energy and lighting performances for energy-efficient lighting system installed in a workshop adopted simple prediction methods in demonstrating the lighting savings that can be achieved using energy efficient techniques. Radulovic *et al*. (2011) investigated energy management in the public lighting of the Croatian city of Rijeka. The study revealed that replacing incandescent bulbs with energy efficient bulbs reduces energy consumption. The authors argued that there is a substantial relationship between investment in energy efficient public lighting and the reduction of greenhouse gases (GHGs) emission. According to Hee and Ku (2014), buildings in university campuses have the capacity for energy consumption reduction in the range of 6 and 30 %. Trifunovic *et al.* (2009) presented a general approach that can be used in the estimation of the reduction in electricity consumption, its market value and the reduction of the peak power demand through retrofitting with energy efficient lamps. The study findings indicated that it is possible to achieve a saving of up to 419.7 GWhyear^{-1} on the Serbian power system using Compact Fluorescent Lamps (CFL).

The feasibility of reducing lighting electricity consumption by replacing incandescent bulbs with CFLs in 18 United Kingdom households indicated that households could save up to 50.9 % (Wall and Crosbie, 2009). The result of a study on the energy management program conducted at the Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM) showed that the quantity of energy saved in 2011 compared to 2010 is about 14 % of total energy that UTM saved while a reduction of EEI among the buildings in the faculty ranges between 5 % and 14 % (Sukri *et al.,* 2012). Ganandran *et al.* (2014) presented the result of a research on the prospective of energy saving of the lighting systems at selected buildings of the Universiti Tenaga Nasional. The study proposed retrofit scenario and estimated the potential electricity saving, the payback period, and the potential environmental benefits. The result of the life cycle analysis reveals a payback period of four years on investment.

Furthermore**,** Mahlia *et al.* (2005) conducted cost-benefit analysis and emission reduction of lighting retrofits in the residential sector. The results of the analysis put the total potential monetary savings to be RM 141 million for 25 % retrofit, RM 282 million for 50 % retrofit and 423 million 75 % retrofit for 5000 operation hours of efficient lighting. Mahlia *et al*. (2011) investigated the life cycle cost analysis and payback period of lighting retrofit at the University of Malaya. The authors found that the T5 lamp is most suitable for retrofit system and has about 40 % potential energy savings among the three samples of retrofit systems investigated. It was discovered to be cheaper compared to the T8 electronic lamp and the HPT8 lamp. Abolarin *et al.* (2013) investigated the amount of carbon dioxide emission and energy consumption that can be saved through lighting efficiency improvement of four University of Lagos halls of residence. Jaja hall of residence was found to release the highest amount of carbon dioxide into the atmosphere due to its huge structure, which resulted to its high power demand.

The lighting system is responsible for the main electricity consumption of any educational facility or building which sometimes consume as high as 42 % of the total energy. Applying energy efficiency technique to the energy consumption of lighting systems in educational buildings and facilities will drastically reduce the cost of lighting systems and by extension, cost of energy and the amount of carbon dioxide emitted to the environment, which decreases the quantity of greenhouse gases. Presently in Nigeria, adoption of energy efficiency and conservation techniques in public buildings is low and undocumented. This is due to the ignorance of the various benefits of such practices. This study therefore focuses on how to enhance the reduction of the amount of energy consumed, the cost of electricity, and the amount of carbon dioxide emission in an educational building facility.

The case study for this research is the University of Lagos- a public university in Nigeria. A preliminary investigation revealed that fluorescent tubes and incandescent bulbs majorly constitute the lighting system. Most of these fluorescent and incandescent bulbs are powered by diesel generators whenever there is power outage from the utility company (Eko Electricity). Distribution Company. The high demand of electricity and sometimes its non-availability from the utility company, often times lead to running the University loads on diesel generators. This increases the cost of electricity bills and GHGs. There is, therefore, the need to embrace an energy efficient system that will enhance the efficient use of allocated power from the utility company in order to achieve a green environment, which is less harmful and environmentally friendly. In addition, the need to cut down the amount of energy consumed through lighting also makes this study desirable.

2.0 METHODOLOGY

A survey was conducted to evaluate the lighting system used in the classrooms at the seven departments of the Faculty of Engineering, University of Lagos, Lagos, Nigeria. It explores the colour rendering index, luminous efficacy, lifetime, ballast factor, annual operational hours, unit lamp cost, unit cost of energy, total power rating, total lumen, and annual energy consumption of three types of lamps. In this study, CFL and LED were adopted against fluorescent bulbs.

Data for this research was gathered through a 'walk-through' energy audit and personal interviews of students and porters based on a structured questionnaire. Faculty of Engineering, University of Lagos houses seven departments. Before the retrofitting, all of the lighting fixtures present in the faculty were the 1.2 metre fluorescent fittings. Due to the presence of ballast, the fluorescent fittings become unreliable towards the end of its lifetime. Based on interviews and the knowledge of energy efficiency, the following assumptions were made:

1. The lecture rooms are occupied for an average of 280 days annually
2. The average use of energy by the lamp fixtures is 9 hr per day during the lecture period and 24 hours during the two weeks of examination periods (due to Night reading)
3. Though LED was actually installed, as replacement, the use of CFLs was also investigated
4. 100 % demand factor on all lamp during operational hours (i.e. no lamp was switched off)

The existing lighting fittings were basically the 2 ft and 4 ft fluorescent tubes. The proposed technologies are efficient, easy to install, have a higher lamp life and reduces energy consumption thereby limiting CO_2 emission. Technical comparison of the existing lighting systems with the proposed technologies is shown in **Table 1**.

Table 1: Technical Comparison of Lamps

Lamp type	Colour rendering index	Luminous efficacy (lm per W)	Lifetime (hours)	Ballast factor
Fluorescent	60-90	40-100	6,000-45,000	0.88
CFL	60-90	50-75	6,000-15,000	1
Incandescent	90-100	5-25	1000	1
LED	70-90	Up to 160	100,000+	1

A comparative analysis of different characteristics of the three different lamps as shown in **Table 2** was conducted. It outlines the annual operational hours of the lighting systems, luminous efficacy, unit cost of lamp, lifetime as well as the total lumen of the lamps. The LED has the highest luminous efficacy and has a lower power rating. The CFL recorded the highest total lumen. The pictures of fluorescent tube (FT), CFL and LED lamps used in this study are displaced in **Figure 1**.

Figure 1: FT, CFL, and LED lamp (Stockypix.com)

Table 2: Comparison of the characteristics of the three different lamps

Parameter	Existing FT	Proposed (CFL)	Installed (LED)
Number of Lamps	587	587	448
Lamp rating (W)	43.30	26.00	16.00
Luminous efficacy (lm/W)	15.70	60.00	70.00
Annual operational hours (hrs)	2,920.00	2,920.00	2,920.00
Unit Lamp cost (USD)	0.30	10.00	42.50
Life time (hrs)	750.00	10,000.00	50,000.00
Unit Cost of Energy (USD/kWh)	0.14	0.14	0.14
Total power consumption (W)	25,417.10	15,262.00	7,168.00
Total lumen (lm)	399,048.47	915,720.00	501,760.00

2.1 Electricity Consumption

A total of 10 lecture rooms were identified to have the FT totaling 587. The fitting operate for an average of 9 hour a day. Other information from the survey is given in **Table 2**. Using the data from the energy audit survey, energy consumption of classrooms in the Faculty of Engineering at University of Lagos was estimated. The Total Energy Consumption (TEC_i) of particular lighting technologies is the product of the number of lamps (N_L), watt rating of lamp (WR_L) per fixtures as well as the operational hour (OHR_L) of the lighting. Equation 1 gives the annual energy consumption of the existing technology as:

$$TEC_i = N_L \times WR_L \times OHR_L \times 0.001 \qquad (1)$$

2.2 Energy Savings

Energy saving (E_{se}) in kWh, which is the difference between energy consumption of the existing and the retrofit lighting system, is estimated using Eq. 2. The Energy Saving can also be expressed in terms of bills savings. This is usually expressed in cost per annum (e.g. $\$yr^{-1}$). This was estimated using Eq. 3. It is the product of energy saving and electricity tariff.

$$E_{se} = TEC_{ex} - TEC_{ret} \qquad (2)$$

$$E_{Bsc} = E_{se} \times E_{tarrif} \qquad (3)$$

Where TEC_{ex} is the total energy consumption by existing lighting technology, TEC_{ret} total energy consumption by retrofitted lamps, E_{Bsc} is energy savings in terms of cost (bill savings), and E_{tarrif} Electricity tariff.

2.3 Oil Equivalent of Energy Saved (OEES)

According to Abolarin et al. (2013), the oil equivalent of energy saved was estimated using Eq. 4. It is the quantity of crude oil saved or conserved as a result of energy efficiency practices. For this study, the energy efficiency measure is retrofitting. The reduction in demand also results in reduction in the fuel used in powering the lighting loads.

$$OEES = \frac{E_{se}(kWh) \times 1\ tonne\ of\ oil\ equivalent\ \times 1 year}{1000\ W \times 12000 kWh\ \times 1 year \times 1 day} \tag{4}$$

2.4 CO_2 Reduction

Annual reduction in CO_2 emitted is the difference in the CO_2 emitted at pre-implementation stage of retrofitting, and the post-implementation stage. The CO_2 emission by any particular technology is evaluated using Eq. 5.

$$EM_{CO2} = \frac{E_{se}(kWh) \times 1.25 \times 10^{-3} \times 1 year}{1000\ W \times 1 kWh\ \times 1 year \times 1 day} \tag{5}$$

2.5 Life Cycle Cost

'Life Cycle Cost' (LCC) is the best method for analysing the economic viability of retrofitting. The LCC takes into account all of the costs of possessing a product or system over a period of time or lifetime. LCC analysis comprises the time value of money, and estimates the present worth of all costs anticipated. This is given as in Eq. 6:

$$LCC = C_c + M_c + E_c + R_c \tag{6}$$

Where C_c is the initial cost of acquiring the entire system, M_c is the maintenance cost, E_c is the energy cost and R_c is the replacement cost.

2.6 Simple Payback Time (SPT)

'Simple payback time' is a technique used in determining the specific time (in years) when the preliminary investment is paid off. Various methods are used in calculating payback. It can be evaluated using either the present value amounts or the cash flow amounts. It refers to the time it takes for an initial investment to be recovered. This is given by Eq. 1, where NPC is the net project cost, and $NAS\_$ is net annual savings. It can be estimated using Eq. 7.

$$SPT = \frac{NPC}{NAS} \tag{7}$$

2.7 Net Present Value (NPV)

NPV is the present value of future cash flows, less the present value of the investment cost. This can be obtained using Eq. 8:

$$PV = -C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i} \tag{8}$$

Where C_0 is investment at year 0, C_i is cash flow at year i, r is the appropriate interest rate (discount rate), and T is the life span of the project. The internal rate of return (IRR) was also used as an economic index for evaluating the economic viability of the proposed lamp fittings. The IRR is the discount rate at which the base cases (the FT) and current system (CLF and LED) have the same net present cost.

3.0 RESULTS AND DISCUSSION

Results from energy consumption analysis, energy savings, net present value, simple payback period, oil equivalent saved, and CO_2 emission are presented in this section.

The present case study falls under the C3 category of the energy tariff in Nigeria. The cost of energy for this category is N27.00kWh^{-1} (\$0.135kWh^{-1}). This was used to estimate the operational cost through the lifetime of the lamps. Energy consumption for the florescent fixtures and the proposed and installed fixtures (CFL and LED tube) were estimated. Results show that the LED consumed the least energy due to the low watt rating and high luminous efficacy available from the LED source. On the other hand, the fluorescent consumed the highest energy with 74,217.93kWh annually, while the utilization of CFL and LED provides 40 % and 73 % reduction in annual energy consumption respectively in comparison to the conventional fluorescent tubes. The annual energy savings in terms of electricity bill show that $4,003.14 could be saved, if CFLs are deployed; while $ 7,193.80 could be saved by utilizing LED tubes in place of the existing fluorescent tubes. With the existing light fittings serving as a basis for comparison, the economic indices of the proposed lighting fittings are given in **Table 3**. The SPT for the CFL and the LED is less than two years, making both of them viable. The $ 35791.76 discounted NPV of the LED is higher when compared to that of the CFL. The cash flow chat is shown in **Figure 2**. Moreover, the life cycle cost (LCC) of the LED is the lowest of the three lighting options.

Table 3: **Economic Indices for the CFL and LED Lamps**

Index	Proposed CFL	Proposed LED
SPT (yrs)	1.01	1.04
IRR (%)	52	36
NPV (USD)	15,261.43	35,791.76
LCC (USD)	188,724.00	76,352.64

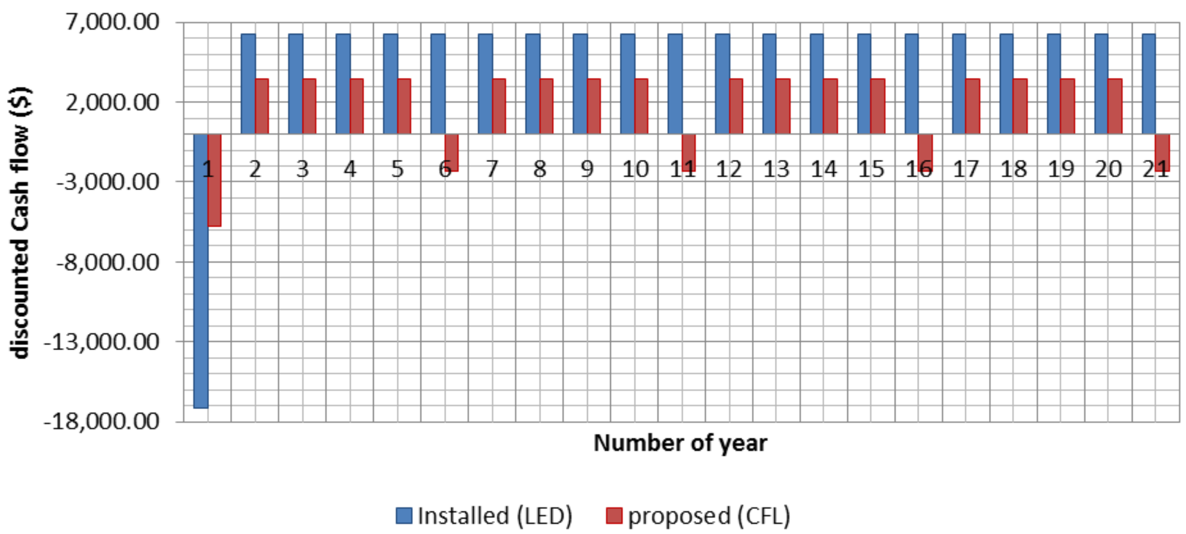

Figure 2: Cash flow for LED and CFL retrofits for a period of 20 years

Figure 3 presents the differences in annual total power demand; annual oil equivalent of energy consumed, and expected CO_2 emission due to the use of the three lamps' options. As a pilot study, the actual retrofitting was carried out at the Faculty of Engineering - University of Lagos, Nigeria; using the LED lamps. Initially, the lecture rooms had been illuminated using the conventional fluorescent tube lamps. **Table 4**

summarizes the estimated savings in annual energy consumption, CO_2 emission reduction and the oil equivalence of energy saved with the implementation of energy efficiency measures.

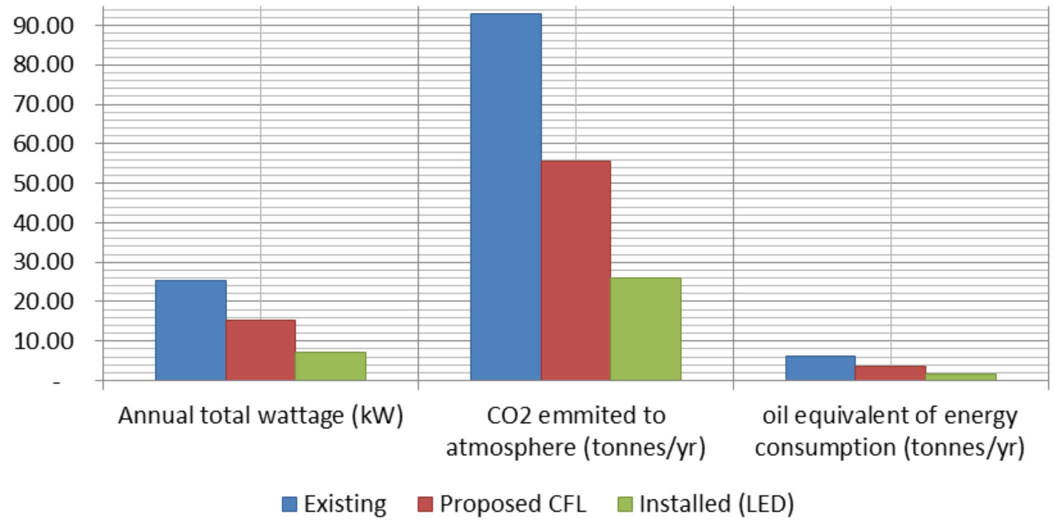

Figure 3: Comparison of annual power consumption, CO_2 emissions, and oil equivalence of energy consumption due to the types of lighting system used in the faculty buildings

Table 4: Summary of estimated savings in watt, energy consumption, and CO_2 emission

Item	Quantity			
	Existing (FT)	**Proposed (CFL)**	**Installed (LED)**	**Unit**
Total power rating	25.42	15.26	7.17	kW
Annual Energy consumption	74,217.93	44,565.04	20,930.56	kWh
Overall daily hour of use	9	9	9	hr
Average no of working days in a year	280	280	280	days
Oil equivalent of energy Saved	0	2.47	4.44	Tonnes
CO_2 emitted to atmosphere	92.77	55.7063	26.16	Tonnes
Savings in CO_2 emission	0	39.95	71.80	%

4. CONCLUSION

Energy efficiency and conservation measures have been proposed in this study to enhance a reduction in energy consumption, energy cost, and CO_2 emission in lecture rooms at the University of Lagos. This involved the retrofitting of inefficient conventional fluorescent bulbs for high quality LED tubes, which resulted in the reduction of CO_2 emission by about 72 %.

The retrofitting process indirectly also reduced environmental pollution with its greenhouse gases (GHGs) emission. The study has revealed that implementation of energy efficiency techniques and the standards for lighting systems are economically feasible. Though the initial implementation cost for the energy efficient lamp technology was higher, consumers will eventually get lower electricity bills through the longer useful life span of such lamps, making them favourable in the long run.

Energy consumers should be encouraged to adopt the use of efficient lighting technologies to replace existing less efficient lightings in commercial, public, and residential buildings. This result can be implemented in all universities in Nigeria. This will result in massive energy savings and emission reduction across the country. Since energy efficiency and conservation techniques are beneficial in several ways, it is expected that this study will offer insights and direction to policy makers, individuals, governments, practitioners and related organisations especially in developing countries. The techniques will reduce energy consumption, GHGs emitted due to the consumption of conventional sources of energy and as well conserve energy for the future generations.

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